SCIENCE

Vol. 87 | Friday, January 7, 1938 | No. 2245

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKeen Cattell and published every Friday by

THE SCIENCE PRESS

New York City: Grand Central Terminal

Lancaster, Pa. Garrison, N. Y.

Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

MAGNITUDES AGAIN[1]

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(1) A Yardstick without Substance

An assemblage of astronomers scarcely needs reminding that stellar magnitude is the measuring stick with which we sound the depths of space. Upon this unit, in some way or other, depend our distances of all the more remote objects in the heavens and, indeed, the dimensions of the universe itself, as far as we know it. Triangulation, the perspective-sharpening of star streams and the backward sweep of stars which reflects our own forward motion through space locate our nearer neighbors; but we quickly pass the useful limit of such methods and thereafter must deal with distances so great that no change in the position of the observer produces any answering shift in the faraway star. The principle of measurement is exhausted, and a new one must be found.

You all know how this need has been met: The intrinsic brightness of an object being known—how we find that item is of no concern here—we observe its apparent brightness, which is only intrinsic brightness dimmed by distance, and apply the faithful inverse-square law. Magnitude is, of course, only a convenient numerical expression of the brightness. A sound and satisfying principle, you say, which meets our need admirably. It oversteps ordinary limits of distance and demands only that the object send us enough light to tell us what it is, and thus enable us to say how bright it is intrinsically.

As astronomers you know that in practice matters are not quite so simple as this expression of the essence of the problem would imply; but I have ignored difficulties in order to emphasize once more that stellar magnitude, our customary measure of brightness, takes rank as an observational datum of major importance.

[1] Address of the retiring vice-president and chairman of the section on astronomy, American Association for the Advancement of Science, Indianapolis, December 28, 1937.

(2) BRIGHTNESS AND SOME CIRCUMSTANCES

At this point some one remarks, But what is brightness? The questioner, if not a physicist, at least will be a physical-minded individual primed with an array of facts about radiation. Well, the brightness in question depends upon circumstances; and, with that, a fringe of uncertainty envelops the problem to the distraction of the observer and the confusion of those who would interpret his results.

One of these circumstances may be the human eye, with its peculiar distribution of retinal sensitivity to both color and intensity and subject to such disturbance of sensation as the Purkinje phenomenon. And, besides, eyes, like height and other physical characteristics of the individuals to whom they belong, differ. Statistically, we may talk about an average eye, but the brightness of a star is not measured by a statistical fiction. The individual human eye that actually does the job is likely to differ so erratically from the fiction that as an instrument for measurement it inspires us with no high confidence.

Another circumstance very probably will be a photographic plate, one of the numerous brands to be had in the market. In these days all workers in physical science know something about plates and the surprises they may spring on the unwary. No two, even from the same box, are exactly alike. Genetically they may be identical twins; but, unless treated with the most meticulous impartiality, they are likely to suggest divergent strains of heredity. Then, too, photographic plates may display a Purkinje phenomenon of their own. It by no means follows that a plate showing the same responsiveness to red and blue light of specified intensities will maintain that equality of response when the intensities are increased or diminished ten or a hundred fold.

Still another possible circumstance is the photoelectric cell, which, with all its precision, has its own peculiarities; and in its behavior always differs from both the eye and the photographic plate.

A totally different kind of circumstance is the atmosphere that envelops the earth; and still others are the glass of the objective and the silver or aluminium surface of the mirror in the telescope with which stars are observed.

The eye, the photographic plate and the photocell operate as receivers and, with various auxiliaries, as recorders of radiant energy; the atmosphere and the image-forming parts of the telescope, however useful they may be in other particulars, behave as unwanted filters which strain out a regrettable fraction of the radiation falling upon them. The dull red globe of the setting sun contrasted with its midday brilliance shows in exaggeration what our atmosphere may do to the color and the intensity of radiation. The changes depend on the momentary state of the atmosphere and the distance of the star above the horizon. They fluctuate from night to night, and sometimes from hour to hour, with the capriciousness displayed by all meteorological phenomena.

The silver coat of the ordinary reflecting telescope deteriorates rapidly and thus also modifies, unpredictably, the color value of the radiation passed on to the photographic plate, or whatever may be used as a receiver. The objective of a refracting telescope at least has the merit of permanence; but the filtering effect of objectives varies between wide limits, and no objective behaves exactly like a reflecting surface of silver or of aluminium.

As a final complication in the measurement of brightness, in photographic photometry at least, the recorded brightness varies with the position of the stellar image relative to the optical axis (distance from the center of the plate) and often on the size of the image as well. Although a time-consuming nuisance, this difficulty can be overcome with patience and may be forgotten for the moment to brighten a little a rather gloomy outlook.

(3) MAGNITUDE, FROM PHYSIOLOGY TO PHYSICS

Having passed in review an array of circumstances which modify measurements of brightness, it is time that I say something about brightness itself. Any such statement, if illuminating, will include a few sentences of astronomical history, interesting as well as important because they concern the rather unusual transfer of a physiological concept into the realm of purely physical concepts and units.

Originally, brightness referred to the intensity of the visual sensation produced by a luminous object; and even now to most people it probably has only that old connotation. And the magnitudes—perhaps Ptolemy's, perhaps from Hipparchus three hundred years earlier, but at any rate preserved and transmitted to us by Ptolemy's catalogue of 1,800 years ago—those ancient magnitudes, which are the ancestors of record of all our magnitudes to-day, are simply rough estimates of visual sensation. More or less accidentally these estimates acquired a numerical expression, accidentally because the six classes of brightness into which the naked-eye stars originally were sorted happen to have been designated by numbers.

In the centuries following Ptolemy an occasional figure of distinction, Al Sufi, Ulugh Beg, Tycho, for example, gave the matter enough attention to repeat, or in some cases revise, the ancient estimates. Later, Ptolemy's system was extended to telescopic stars. Flamsteed, Lalande, John Herschel, Bessel and especially Argelander and Schönfeld observed literally hundreds of thousands of stars; but all these observa-

tions were still simply estimates of visual sensation, and, aside from some numerical refinement, nothing very essential happened until the discovery of Fechner's psycho-physical law in 1859. Expressing as it does a relationship between sensation and the stimulus producing the sensation, this law gave for the first time a rational statement of the connection between the subjective experience of brightness and the objective physical cause. That Fechner's law has only limited applicability is not now of much consequence for photometry. The significant point is that its form determined the course of subsequent events.

You recall how the law runs—that the *absolute* change in sensation is proportional to the *percentage* change in the stimulus. Applied to stars and set down as a formula, it leads to the familiar relation that the difference in the magnitudes of two stars is proportional to the logarithm of the ratio of the intensities of the light we receive from them. This relation was first discovered empirically by Steinheil in 1836 and later verified by others; but it was Fechner's fundamental investigation that gave it the vitality which insured fruitful applications.

There was, of course, the question of units and zero point, which need detain us only to remark that whoever first sorted the lucid stars into six classes unwittingly assigned to unit magnitude the value it has to-day. Again you will recall what happened. Actual measurements of starlight with photometers, which had meanwhile been devised, showed that an intensity ratio of 1 to 100 in the light of two stars corresponded so closely to a difference in brightness of five magnitudes on the traditional scale that this convenient numerical relationship was adopted as a definition of unit magnitude.

You will observe that magnitude now appears in physical dress. Starting as an expression and measure of sensation, magnitude maintained its physiological aspect for centuries; then suddenly the physiological unit disappears to be replaced by a new unit, bearing the same name and of sensibly the same numerical value as the old one, but defined in terms of physical concepts. In fact, magnitude difference thus becomes only a mode of expression for relative intensity—that is, of the relative energy flux per unit area received by the observer. Following tradition, we still speak of magnitude as a measure of brightness; but the brightness meant is concerned not with the subjective features of sensation but primarily with properties of stellar radiation.

It is also noteworthy that these ideas adapted themselves easily to the conditions of photography when this substitute for the eye found use in the measurement of starlight. The source of this welcome simplicity is a certain rough analogy between the eye and the photographic plate. A significant characteristic of the photographic image of a star, and the thing the most easily measured, is its size. But both size of image and photographic density, an alternative and sometimes more advantageous expression of the photographic effect, resemble the subjective sensation of brightness: To a first approximation, both bear a logarithmic relation to the intensity of the external exciting cause. Consequently, the characteristics usually measured on the plate stand in a simple, nearly linear relation to the physical stellar magnitude. Photographic magnitudes thus naturally ranged themselves alongside those derived, first, by visual estimates and, later, from visual measurements of intensity made with photometers.

But since physical concepts have so come to the fore, you ask, Why not express measurements of intensity directly in energy units, thus obtaining results of immediate physical significance? It is not tradition alone that has so firmly established the physical concept of magnitude. We still make visual estimates of brightness, or better, of differences in brightness; the step method of Argelander, for example, is still of great value. And for easy comparison of results we prefer the traditional unit. Then, too, there is a further item of convenience. We deal to-day with intensities differing as much as a hundred million to one. The awkwardness of such numbers is obvious; but put them in logarithmic form, as we do when we turn them into magnitudes, and three or four significant figures suffice to express the entire range of relative intensities with all needed precision.

So much for that rather ambiguous term, brightness, and its dual connection with visual sensation and with physics. Its clarification has given us magnitude, which, although suggestive of its own historic origin, is only a convenient mode of expressing energy received per square centimeter per second of time. Now we may turn back to those attendant circumstances which in specific cases determine what magnitude is to be.

(4) Circumstances Again, and a Formula

Stars behave enough like black bodies to suggest that the range in wave-length of the radiation they emit is large. We can measure, however, only the radiation transmitted by the earth's atmosphere, extending from the abrupt cut-off at wave-length 0.29 μ due to the broad ozone band to an upper limit which, with some gaps, now stands close to 23 μ—an interval of about six octaves. The range for the eye is a little short of an octave. The photographic plate and the photocell may or may not—usually not—do a little better. Further, the restricted ranges of sensitivity for these receivers of various kinds do not coincide.

Ordinary magnitudes therefore bear no simple relation to the total energy radiated by stars and, moreover, are of diverse kinds—visual, photographic, photovisual, photoelectric, for example.

The facts for a given case may be stated symbolically by the formula:

$$M = -2.5 \log \int_0^\infty \frac{\pi r^2}{\zeta^2} E(\lambda, T) A(\lambda, z) T(\lambda, d, m) R(\lambda, m) d\lambda + \text{const.} - 2.5 \log \frac{\zeta_0^2}{\zeta_0^2}.$$

Mathematically, this forbidding expression for the apparent magnitude of a star is definite enough; but in practice its symbols remain for the most part undetermined. Nevertheless, the equation is useful because it illuminates the concept of magnitude and, at the same time, sets up finger posts pointing toward possible dangers. It expresses a proportionality between magnitude and the logarithm of the energy flux received per unit area at the point of observation (ergs sec^{-1} cm^{-2}), multiplied by certain reduction factors and summed over the entire range in wave-length λ. The factor 2.5 is Pogson's coefficient, which fits the unit for m as closely as possible to the system of the early visual estimates. The minus sign records a minor accident of history—that whoever first assigned numbers to the six original classes of brightness pinned the numeral "one" to the brightest stars, instead of the other way around. The constant of course fixes the zero point for the magnitude scale. The purpose of the superfluous zero term involving ζ_0 will appear in a moment.

Thus far we have only a formal statement of tradition adjusted to the needs of precision. As for the details of the equation, a little dissection proves it less incomprehensible than it looks. Clearly there are four functions, each dependent on the wave-length, and, potentially at least, on other things too. The distance of the star, ζ, and its radius, r, are thrown in for good measure, to remind us that apparent magnitude does depend on the distance and the size of the star and to enable us to begin with E, the energy function of the star, whose emission is determined by its temperature T.

E, here expressed as surface intensity (energy flux for the wave-length interval λ to $\lambda + d\lambda$ per unit solid angle summed over unit area of the radiating surface), is, of course, peculiar to the star—in general, however, a more-or-less close approximation to the black-body law of the perfect radiator. Together, E, r and ζ give us the energy flux received per unit area just outside our atmosphere—you will recall that hitherto we have always talked about energy received. A and T express the fractions of incident energy which escape the filtering action of the atmosphere and the telescope. Besides λ, the zenith distance of the star, z, and its distance from the optical axis of the telescope, d, are involved here, and possibly also m itself, which may influence the distance correction. Finally, R stands for receiver and measures the fractional response of the eye, plate or photocell; in short, it is the sensitivity-curve which determines what kind of magnitude m is to be—visual, photographic, photovisual, etc. The appearance of m in this function is a warning to be on guard against the Purkinje phenomenon.

The zero-point constant involves more than one might think and deserves comment. In practice it is always the magnitude of another star, some standard reference object, and hence 2.5 times the logarithm of an integrated intensity precisely similar to the first term on the right of the formula. The entire expression is therefore the equivalent of the logarithm of a quotient. This circumstance has the important consequence that the numerical value of m is independent of the particular physical units used for its definition; we might, for example, have used energy density instead of energy flux. And hence it is that astronomers sometimes talk of magnitude with such unconcern for the physical significance of the thing with which they are dealing. It is only when the standard reference object is compared with a terrestrial source for reduction to absolute units that there must be careful watching of steps if confusion and error are to be avoided.

Another matter of real importance lies hidden in the constant: If the reference object and the star in question are of the same spectral composition, and if both are observed under the same conditions, with precautions to avoid the Purkinje phenomenon, all the functional relations, as well as the physical units, drop out from the quotient and we are left with the ratio of the *total* energies radiated by the two stars. In particular, the receiver with its restricted range of sensitivity cuts no figure, and in the case of visual magnitudes the last trace of a connection with physiological sensation disappears.

Finally, as for the apparently meaningless term in ζ_0, this intrusion shows how easily magnitude becomes a magic wand for summoning forth distances of stars. Interchange ζ_0 in the denominator of this term with ζ in the first term. The value of m remains the same. The first term on the right, however, together with the constant, becomes m_0, the apparent magnitude of the star seen from the distance ζ_0. Think of ζ_0 as a conveniently chosen standard distance, ten parsecs in practice, to which the light of all stars may be referred as a means of revealing their differences in intrinsic brightness. The quantity m_0 is, accordingly, the so-called absolute magnitude of the star, usually denoted by M. The zero term is no longer zero, but a simple function of the star's distance expressed in ζ_0 as a unit.

We thus obtain a relation which shows, as already said, that m is only the intrinsic brightness of a star dimmed by distance,[2] and from which distance may be found when absolute and apparent magnitudes are known. The status of magnitude as a yardstick of distance justifies this digressive paragraph on so familiar a relation.

It is doubtless a happy circumstance that Hipparchus and Ptolemy did not know about this formula, even without its superfluous term. Naïve approach to a problem often has insured its solution.

With such a statement, this part of my discussion seems to be nicely rounded off to a finish; and not so many years ago it might have been left at that. But to-day we know too well that light gets lost on its way through space for us to be deceived by a rhetorical ending. Nevertheless, I do not intend to say here what interstellar absorption does to our formula, but only let you know that it has not been wholly forgotten. It modifies our conclusions, of course, but does not greatly affect the observational procedure. Usually we measure magnitudes as though absorption were not present, and then from our results try to find if it is present, and to what extent.

(5) THE FOUNTAIN OF TROUBLES

Viewed in the light of the unpredictabilities described for eyes, photographic plates and the atmosphere surrounding us, our symbolic expression shows why photometry to some extent stands in bad repute. And that is part of the value of the formula, which although not usually a basis for either observation or calculation is an excellent summary of the ways in which uncertainties get into our results.

To illustrate, note again that each of the functions E, A, T, R depends on the wave-length λ. Each element of the surface intensity E under the summation sign is modified in succession by A, T and R. If now A, T and R change, that is, if the conditions of observation change, the modifications themselves are modified, and in a different way for each small interval of wave-length. The effect on m depends on the sum of these incremental changes. Moreover, since E depends on the temperature of the star, the disturbance in m produced by changes in the atmosphere, the telescope and the receiver also depends on stellar temperature; blue stars behave differently from red stars.

The ideal of observations made always under the same conditions can not be attained. The visual observer must use his own eye and the telescope at hand. We might agree all to use the same kind of photographic plate, treated in the same way or the same type of photocell; but it is not worth while, because the telescope with which the observations are made can not be standardized.

Important departures from uniformity in the observational data are therefore inevitable. Each observer can standardize the conditions affecting his own measures—the use of his eyes, the handling of his plates, the arrangement of his observations; and he can attend to the erratic behavior of the atmosphere by observing different stars at nearly the same altitude and always as close to the zenith as possible. To utilize the high precision of the photocell, he can be even more cautious, testing the atmospheric transmission from night to night and treating different stars appropriately to their colors. All this may be done; but in the end we face the unyielding fact that observational results obtained with different eyes and different instruments are inherently inhomogeneous, and, to be of ultimate worth, must be standardized by reduction to a normal reference system.

(6) ANOTHER, ONLY MENTIONED

Before passing to the logical sequent of the preceding paragraph I must again call your attention to the coefficient 2.5, unobtrusive, even though at the forefront of the symbolic expression for magnitude. The true inwardness of this number is revealed by noting that its reciprocal, 0.4, is the logarithm of the ratio of two intensities whose difference in brightness is exactly one magnitude—the essence, therefore, of the definition of unit magnitude and, as such, the center of the struggle for law in the millions of m's to be found in our catalogues. In short, this coefficient of Pogson's fixes the scale of magnitudes.

To find the magnitude of a star in accordance with this scale naturally requires some kind of measurement of the intensity of starlight. Beyond a statement of principle and a rather obvious inference, I do not intend to say anything about such measurements here. The subject is long and involved; moreover, some of the more serious difficulties originate in matters already mentioned and still to be discussed.

As for method, usually we reduce the light of a star by a known amount—with the aid of a diaphragm, a grating, a screen, a pair of polarizing prisms or some equivalent device—then find a second, fainter star whose intensity, unchanged, produces the same effect on the eye or the photographic plate as the reduced intensity of the first star. The logarithm of the reduction factor, multiplied by that critical coefficient 2.5, is the magnitude difference of the two stars. We thus proceed by an equalization of intensities, equality in intensity being judged by likeness in visual or photographic effects.

The practical outworking of this principle affords endless opportunity for ingenuity in avoiding or elimi-

[2] Except in the rare case that the star's distance is less than ten parsecs; then the apparent magnitude is brighter than the absolute value.

nating a great variety of disturbances that may influence the accuracy of the magnitude scale. But whatever the effort, the precision in the scale always falls far short of that easily attained in measurements of things that can be touched or weighed.

Under favorable laboratory conditions judgments of equality in visual and photographic effects are uncertain by about one per cent.; but actual observing conditions are always far below those of the laboratory. The interval measurable in a single step seldom exceeds two or three magnitudes, corresponding to an intensity ratio of, say, 15 to 1. Since modern telescopes encompass an interval of twenty magnitudes, or a ratio of a hundred million to one, many successive steps are required to cover the entire range. Any systematic error of measurement is cumulative and easily becomes serious, while the accidental errors alone swell to an unpleasant total.

(7) An Achievement—We Hope

The practical derivation of magnitudes follows two main lines, seeking, first, standards of magnitude—precise values for a relatively small number of stars covering a wide range in brightness; and second, utilization of such standards in measurements of other stars, sometimes an individual, sometimes a group, and sometimes the thousands of stars required for statistical discussions relating to the size and the structure of our stellar system.

Although there are details enough to keep the observer nimble-witted, the transfer of the scale of a group of standards to stars in other parts of the sky follows a comparatively simple procedure; and properly used, the process gives reliable results.

Standards themselves require more attention. To set them up the scale of magnitudes defined by Pogson's coefficient must be established by methods outlined briefly a moment ago. This part of the problem we now hope is mostly a matter of history. For fifteen years the North Polar Sequence has served reasonably well and probably represents the most anxious part of the effort required to establish a satisfactory system of reference magnitudes.

Selected by Pickering, only a few stars at first, this famous list of standards had by 1912 grown to the 96 objects now familiar. Extensive measurements at a half dozen observatories gave finally the list of mean magnitudes presented to the International Astronomical Union in 1922. The photographic scale is covered from magnitude 2.5 to 20.1; the photovisual, from 2.1 to 17.4. Below 19.0 and 15.5, respectively, the means include only a few Mount Wilson observations and scarcely deserve the sanctity of standardization.

Please note that these standards do three things: serve as exemplars of the photographic and the photovisual scales; fix the zero points of both scales; define a reference system of colors for stars. This is a good order in which to state the facts; but to talk about them we begin with the notion of standard colors.

Reflection on the formula for magnitude has shown us that results as they come from the telescope lack homogeneity, and a little further reflection indicates that to attain homogeneity we require standards of color.

To be more explicit, we note that magnitude derived with an ordinary photographic plate sensitive to the violet and blue usually differs from the visual or photovisual magnitude, corresponding to a maximum sensitivity in the yellow. Together, these two classes of magnitudes constitute a restricted spectral photometry which determines the integrated brightness of two rather wide regions in the spectrum. Even so, the photographic and photovisual magnitudes are sufficient to indicate the temperature of a star; or, as we more commonly put it, the difference of these magnitudes (color index) is a measure of the color of the star. Moreover, since the radiation function of a star (E, in our equation) is approximately that of a black body, the color index turns out to be nearly proportional to the reciprocal of the star's temperature.

Now the differences between separate series of photographic (or photovisual) magnitudes originating in the telescopes, plates, etc., which we designate as inhomogeneities, resemble the differences between photographic and photovisual magnitudes; they are only smaller. These small disagreements between magnitudes of the same kind which cause so much trouble are therefore also proportional to the reciprocal temperature, or, better still, to the color index.

Because of this simple relation, knowledge of color indices opens the way to a unification of series of magnitudes which in themselves are not directly comparable. The procedure of course presupposes a reference system of color. The system adopted for the international standards is that defined by magnitudes obtained with the silvered reflector and plates of the ordinary silver-bromide emulsion.

The zero points fixed by the international standards represent an attempt to satisfy a convention adopted by the Committee of the Astrographic Chart in 1910, namely, that the mean photographic magnitude of A0 stars between magnitudes 5.5 and 6.5 should equal the mean Harvard visual magnitude of these stars. The color index of an A0 star would thus be zero. For the region of the North Pole these conditions are approximately satisfied, the color index for A0 being not quite zero, but − 0.04 mag. instead.

Recently, however, we have found that a thin veil of interstellar dust cloud obscures the stars in the polar

region and makes them about 0.1 mag. redder than normal. Stated in another way, color indices of A0 stars in regions unaffected by selective space absorption which have been derived by comparisons with the polar standards average about -0.14 mag. The convention of 1910 is therefore not generally satisfied and as it stands is incomplete. The sensible thing seems to be to abandon the original definition and accept the Polar Sequence magnitudes themselves as a definition of the zero points, which would thus merely continue a practice already established by fifteen years' usage.

As for the scales themselves, it is hard to say with assurance how closely they fit the definition of unit magnitude. I have already expressed reservation about some of the faintest stars of the sequence. For other parts of the scale the internal agreement of abundant data obtained by different methods and at different observatories has always inspired a good deal of confidence in the results.

The most searching test, however, is one recently made with the photoelectric cell by Stebbins and Whitford. The high precision of this instrument and its complete independence of all the traditional methods of photographic photometry give the test unusual importance. When reduced to the standard photographic scale, the measured interval of about nine magnitudes from Polaris down to magnitude 11.5 agrees within a few hundredths with that shown by the standards. Between 6.5 and 11.5 the systematic differences for groups of four stars each reach 0.02 mag. only once, and the average difference for individual stars is ± 0.017 mag.

The only doubtful point concerns stars 1 to 4 of the sequence, for which there is a mean difference of 0.10 mag. The magnitudes for these stars, which are all of early A type, would seem, however, to require a supplementary correction for color, of the right sign and possibly of the right amount to remove the discrepancy. This correction originates in Balmer-line and continuous hydrogen absorption, which affects the standard magnitudes but not those obtained with the photocell. Since departures from black-body radiation are involved, the required color correction stands in no simple relation to color index and can not be determined from the data now available.

This difficulty illustrates a defect in the Polar Sequence standards: there are not enough of them and they include no B-type stars. Had a representative selection of types been available, the supplementary correction for hydrogen absorption could have been determined directly from the data used for the comparison.

Again, a final reference to our formula reminds us that the transmission function for the telescope may depend on magnitude and on distance from the optical axis and that reductions to the standard color system also frequently depend on magnitude. The observer is certain to meet these conditions in using large-field, short-focus cameras. The number and distribution of the present standards is wholly inadequate to a satisfactory determination of the complicated instrumental corrections required to neutralize these disturbances. To remove this deficiency we have measured at Mount Wilson, in an investigation now nearing completion, photographic and photovisual magnitudes of a large number of stars north of $+80°$ declination and down to about the eleventh photographic magnitude to serve as supplementary standards.

(8) EXHORTATION TO THE OBSERVER

Twice already have I referred to the inherent lack of homogeneity in photometric data. Now admonitions are to follow; most important of all, that the observer either reduce his results to the international system or at least provide the means of doing so.

The discharge of this obligation is less onerous than would be expected from the formal expression for magnitude. Since the corrections required are nearly proportional to the color indices of the individual stars, the calculation is simple. But I must immediately warn you that the expected proportionality of color correction to color index is not always realized. Departures from black-body radiation may interfere, as for example in the early A stars just cited, whose magnitudes presumably are affected by hydrogen absorption. A more detailed investigation is then required.

At this point note a significant detail: If magnitudes are to be reduced to a fundamental system, the colors of the stars, or at least some color equivalent such as spectral type, must be known. These, alas, have all too often remained undetermined; and it is a distressing fact that extensive series of magnitudes, obtained at great expenditure of time and labor, can not now be reduced to the standard system without much added effort. As they stand, these magnitudes have little value, for they can not be combined with other data.

This state of affairs is not usually a mark of indifference on the part of observers, but rather of delayed recognition of the inherent complexity of the problem. Anyway, this is part of the truth. If early realization of the full meaning of magnitude would have been a hindrance to the ancients, it is equally true that the comparatively recent physical formulation of the problem accounts for much wasted effort. We seem to be concerned with a case of arrested development; astronomers have become physicists only within recent decades.

Something else is to be said, however. Measurements of color always lag a stage behind measurements of brightness. The high sensitivity of photographic

emulsions to blue and violet light permits the measurement of photographic magnitudes of stars whose visual or photovisual values are entirely beyond our powers. Moreover, photographic magnitudes, even without colors and consequently without reduction to a homogeneous system, could always serve some useful purpose; and so they were measured, extensively.

But this kind of usefulness is passing, and from the present confusion of photometric data this guiding precept stands clear: That no photometric investigation be undertaken which does not provide for the reduction of its results to the color system of the North Polar Sequence. Stars so faint that their color equivalents can not be determined should be observed only with instruments which give directly results on the international system. Since this system is defined by the ordinary silver-bromide emulsion used with the silvered reflector, and since the most powerful telescopes are reflectors, this demand does not seem excessive.

But you will immediately remind me that we are now in process of transforming all our silvered reflectors into aluminized mirrors. At first this promised to be a serious difficulty; but experiments at Mount Wilson have provided a simple solution. A filter of ordinary crown glass in front of the photographic plate transforms the aluminized mirror into the practical equivalent of a silvered reflector.

(9) Addressed to a Physicist

In the beginning I suggested that physicists have a way with questions. And now that you must hope I am getting near the end of things, some one will surely be ready with a last-chance query: But the total energy radiated by a star; what about that—doubtless to be expressed by some kind of a magnitude? And why be content with a crude spectral photometry that measures radiation at only two points in the spectrum?

Of course we have bolometers, radiometers and thermocouples, devices equally sensitive to radiation of all wave-lengths, and we do use them; but let it not be forgotten that you may take your telescope armed with one of these devices to the top of the highest mountain, point it at a star directly in the zenith, and still fall far short of measuring the total output of stellar energy, especially if the star be a hot one as stars go. The amazing performance of atmospheric ozone still goes on. Equivalent in amount to a thin shell only 3 or 4 millimeters thick at sea-level pressure, it still effectively blocks practically all radiation on the short-wave side of 0.29 μ. At the other end of the spectrum the immigration restrictions are less stringent; and for those remarkable low-temperature stars—the long-period variables at minimum light—the total radiation that passes the guardian molecules of our atmosphere is a thousand times that transmitted by the visual region.

These so-called radiometric magnitudes are immensely important when we look at stars as individual physical machines, because they bring us a step closer to the total energy of radiation, an item undoubtedly of great significance, which by some mystery of notation we designate as the star's bolometric magnitude—a mystery because thermocouples, radiometers and bolometers all measure exactly the same thing. Further, by blocking out various sections of the radiation transmitted by the atmosphere, we obtain with these impartial receivers additional points on the spectral energy-curve of a star and thus learn more of another item of great physical significance.

A Utopia of intellectual and instrumental accomplishment would, I suppose, include the bolometric magnitude and a complete spectral photometry for every star we know; but we do not get very far on the way toward either of these ideals. The part of a star's energy that we catch on our pin-point earth is too slight to stir the impartial recorder far out of its comparative sluggishness, and for all but the brightest stars will stand none of the dilution essential for any proper spectral photometry.

The astronomer, like the physicist, wishes to know about stars as atomic machines; but, impressed by the fact that there is more than one star in the heavens, he has also a mind full of questions about the numbers of stars of each degree of brightness and how they group themselves into systems and a system of systems extending endlessly outward into space. So he works his thermocouple and does his spectral photometry when possible, then compromises upon magnitudes which give, at the same time, measures of color, and hence a little knowledge of physical states; but, finally, for those objects so faint as to be caught only by the tip of the sensitivity curve of his photographic plate he must be content with a magnitude which tells him nothing of stellar conditions but remains a colorless datum to be fed into formulae for distances and distribution that he may learn at least something about the amazing universe of the telescope.

SCIENTIFIC EVENTS

THE VIRGIN PORT ORFORD CEDAR TRACT RESERVATION

Eleven hundred acres of virgin Port Orford cedar timber have been proclaimed a "Natural Area" by order of F. A. Silcox, chief of the U. S. Forest Service, to be kept forever in its pristine condition. This area lies within the Port Orford Cedar Experimental Forest on the South Fork of the Coquille River, which

is a part of the Siskiyou National Forest in Oregon. The withdrawal was made on the recommendation of Regional Forester Buck and Thornton T. Munger, director of the Pacific Northwest Forest Experiment Station, in accordance with a regulation of the Department of Agriculture that "typical examples of the principal forest types shall be reserved, untouched by man, for posterity to enjoy and study." The tract contains groups of cedar and is so situated that it will be safe from inroads of fire and logging.

At the present rate of cutting, virgin tracts of Port Orford cedar will soon be a rarity except on federal lands within the National Forests. The forest survey recently completed by the Federal Forest Experiment Station indicates that there is only about 1,140 million board feet of this cedar in existence, all in southwestern Oregon except for a small amount in northern California. Sixty-nine per cent. of this timber is in private ownership, 15 per cent. on the Oregon and California Railway revested grant lands managed by the Department of the Interior, and 16 per cent. on the National Forests managed by the Department of Agriculture. The annual cut in recent years averages about 48 million board feet, nearly all coming from private lands and from the Oregon and California revested lands.

It is therefore desirable for the U. S. Forest Service to set up some virgin tracts as museum pieces, so that future generations may have lasting examples of this forest tree under natural conditions.

AWARD TO DR. BOWIE

THE Queen of the Netherlands has appointed Dr. William Bowie, retired chief of the Division of Geodesy of the U. S. Coast and Geodetic Survey of the Department of Commerce, an officer of the Order of Orange-Nassau, and has presented to him, through the Minister of the Netherlands, the medallion and diploma of the order.

This honor was bestowed upon Dr. Bowie "in recognition of outstanding achievements in the interests of international science and geodesy, and his collaboration with Dr. F. A. Vening Meinesz, professor of geodesy at the University of Utrecht, the Netherlands, and a member of the Netherlands Geodetic Commission, in the determination of gravity-at-sea."

Dr. Bowie and Dr. Meinesz have worked together many years in the International Association of Geodesy, a branch of the International Geodetic and Geophysical Union. Dr. Bowie was president of that association from 1919, when it was created, until 1933, when he became president of the International Geodetic and Geophysical Union. He was succeeded as president of the International Association of Geodesy by Dr. Meinesz.

It was largely through this association that Dr. Bowie became interested in the work of Dr. Meinesz, who had devised and constructed an apparatus by means of which accurate determinations of the values of gravity can be made aboard a submarine. Dr. Bowie was twice instrumental in bringing Dr. Meinesz to the United States to conduct expeditions for the determination of gravity-at-sea on submarines of the U. S. Navy operating in West Indian waters.

Dr. Bowie was retired from the U. S. Coast and Geodetic Survey in December, 1936, after 41½ years of service, during twenty-seven of which he was chief of the Division of Geodesy.

He has received honorary degrees from Trinity College, Lehigh University, George Washington University and the University of Edinburgh. He holds also honorary memberships in the Academy of Sciences of France, the Academy of Sciences of Norway, the National Academy of History and Geography (Mexico) and the Russian Geographical Society. In 1937, he was awarded the Elliot Cresson Medal by the Franklin Institute of Philadelphia for his contributions to the science of geodesy.

Dr. Bowie is a member of the National Academy of Sciences; the Philosophical Society of Washington, of which he was president in 1926; the Washington Academy of Sciences, of which he was president in 1930; the Washington Society of Engineers, of which he was president in 1914; the American Society of Civil Engineers; the American Astronomical Society, and other leading national and international scientific societies. He is the author of a number of publications of the Coast and Geodetic Survey on the varied branches of geodesy.

LECTURESHIP IN HONOR OF DR. JULIUS STIEGLITZ

DR. GUSTAV EGLOFF, chairman of the Chicago Section Committee of the American Chemical Society, and Dr. Paul N. Leech, chairman of the Alumni Committee of the University of Chicago, have given out the following appeal for funds to establish a lectureship foundation in the memory of Dr. Julius Stieglitz, distinguished chemist and teacher, who died early in 1937:

> You know, through his work and that of his former students, the importance of the contributions made to American chemistry by Dr. Julius Stieglitz, who passed on early this year. In a sense, your company is a beneficiary of his learning and his power to illuminate the subject of chemistry and make it a living thing in the minds of his students.
>
> Those who loved Dr. Stieglitz, who benefited by his instruction and who revere his memory, are contributing to a fund to endow a Julius Stieglitz Lectureship to carry on

his spirit in the teaching of American chemistry. It is estimated that $25,000 will be required for this purpose.

It is hoped to make the lectureship the most outstanding of its kind in the United States. It is to be supervised by a committee appointed jointly by the University of Chicago and the Chicago Section of the American Chemical Society. It is planned to give the lectures one year at the University of Chicago, the next before the Chicago Section of the American Chemical Society.

We feel sure you will agree that this is a well-deserved tribute to Dr. Stieglitz's memory. It will keep his spirit alive and will elevate the quality and increase the quantity of chemical development in American universities, from which your future chemists must come. We are asking only modest contributions. We prefer, as we know Dr. Stieglitz would have preferred, that the fund be an expression of a large number of those in whose hearts he still lives, rather than the large donations of a few. We would appreciate such a donation from your company or from you individually.

Donations or pledges should be sent to Dr. B. B. Freud, Treasurer, in care of Armour Institute of Technology, 3300 Federal Street, Chicago.

INTELLECTUAL FREEDOM

At the Indianapolis meeting of the American Association for the Advancement of Science there was held the first of a series of symposia on science and society, and this subject attracted much attention among the members and from the press. The council of the association passed a resolution, which reads:

Whereas, Science and its applications are not only transforming the physical and mental environment of men, but are adding greatly to the complexities of their social, economic and political relations among them; and

Whereas, Science is wholly independent of national boundaries and races and creeds and can flourish permanently only where there is peace and intellectual freedom; now, therefore, be it

Resolved by the council on this thirtieth day of December, 1937, that the American Association for the Advancement of Science makes as one of its objectives an examination of the profound effects of science upon society; and that the association extends to its prototype, the British Association for the Advancement of Science, and to all other scientific organizations with similar aims throughout the world, an invitation to cooperate, not only in advancing the interests of science, but also in promoting peace among nations and intellectual freedom in order that science may continue to advance and spread more abundantly its benefits to all mankind.

It will be remembered that at the Boston meeting of the association five years ago "A declaration of intellectual freedom" was adopted. This declaration, which was reaffirmed at the Atlantic City meeting last year, is as follows:

The American Association for the Advancement of Science feels grave concern over persistent and threatening inroads upon intellectual freedom which have been made in recent times in many parts of the world.

Our existing liberties have been won through ages of struggle and at enormous cost. If these are lost or seriously impaired there can be no hope of continued progress in science, of justice in government, of international or domestic peace or even of lasting material well-being.

We regard the suppression of independent thought and of its free expression as a major crime against civilization itself. Yet oppression of this sort has been inflicted upon investigators, scholars, teachers and professional men in many ways, whether by governmental action, administrative coercion or extra-legal violence.

We feel it our duty to denounce all such actions as intolerable forms of tyranny.

There can be no compromise on this issue, for even the commonwealth of learning can not endure "half slave and half free." By our life and training as scientists and by our heritage as Americans we must stand for freedom.

OFFICERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

A full account of the Indianapolis meeting of the American Association for the Advancement of Science and the scientific societies associated with it, edited by the permanent secretary, will be printed in the issue of Science for February 4.

Officers for 1938 were elected as follows:

President: Wesley C. Mitchell, Columbia University.

Vice-presidents of the Association and Chairmen of the Sections:

Mathematics (A): J. R. Kline, University of Pennsylvania.

Physics (B): H. E. Ives, Bell Telephone Laboratories, New York City.

Chemistry (C): H. C. Urey, Columbia University.

Astronomy (D): R. M. Stewart, Dominion Observatory, Ottawa, Canada.

Geology and Geography (E): Walter H. Bucher, University of Cincinnati.

Zoological Sciences (F): F. B. Sumner, Scripps Institution of Oceanography, University of California.

Botanical Sciences (G): R. J. Pool, University of Nebraska.

Anthropology (H): Alfred Kroeber, University of California.

Psychology (I): Calvin P. Stone, Stanford University.

Social and Economic Sciences (K): H. R. Tolley, U. S. Department of Agriculture.

Historical and Philological Sciences (L): Nelson G. McCrea, Columbia University.

Engineering (M): A. A. Potter, Purdue University.

Medical Sciences (N): Thomas M. Rivers, Rockefeller Institute for Medical Research, New York, N. Y.

Agriculture (O): R. M. Salter, Ohio Agricultural Experiment Station, Wooster.

Education (Q): George D. Stoddard, State University of Iowa.

Members of the Sectional Committees:

Mathematics (A): J. M. Thomas, Duke University.

Physics (B): L. A. DuBridge, University of Rochester.

Chemistry (C): James F. Norris, the Massachusetts Institute of Technology.

Astronomy (D): Charles P. Olivier, the University of Pennsylvania.

Geology and Geography (E): W. T. Thom, Jr., Princeton University.

Zoological Sciences (F): J. W. Buchanan, Northwestern University.

Botanical Sciences (G): J. M. Beal, the University of Chicago.

Anthropology (H): John Cooper, Catholic University, Washington, D. C.

Psychology (I): Frederic L. Wells, Harvard University.

Social and Economic Sciences (K): Stuart Rice, Central Statistical Bureau, Washington, D. C.

Historical and Philological Sciences (L): Alexander Pogo, Library of Congress.

Engineering (M): J. W. Barker, Columbia University.

Medical Sciences (N): C. A. Doan, the Ohio State University.

Agriculture (O): Richard Bradfield, Cornell University.

Education (Q): F. B. Knight, State University of Iowa.

Finance Committee: Wilson Compton, Washington, D. C.

Committee on Grants: F. K. Richtmyer, Cornell University; G. H. Parker, Harvard University.

Executive Committee of the Council: G. D. Birkhoff, Harvard University; E. B. McKinley, George Washington University School of Medicine.

Trustee of Science Service—nominated: Henry B. Ward, Urbana, Illinois.

SCIENTIFIC NOTES AND NEWS

DR. LYMAN J. BRIGGS, director of the National Bureau of Standards, was elected president of the American Physical Society at the Indianapolis meeting. Other officers elected were: Dr. John T. Tate, of the University of Minnesota, *vice-president;* Professor W. L. Severinghaus, of Columbia University, *secretary,* and Dean George B. Pegram, of Columbia University, *treasurer.*

DR. ROBERT G. AITKEN, director emeritus of the Lick Observatory of the University of California, was installed as president of the American Astronomical Society at the recent meeting at Indiana University. Dr. Henry Norris Russell, of Princeton University, gave the address of the retiring president.

OFFICERS of the American Meteorological Society were elected as follows: Dr. Willis Ray Gregg, chief of the U. S. Weather Bureau, *president;* Dr. George F. McEwen, of the Scripps Institution of Oceanography of the University of California, *vice-president;* Dr. Charles F. Brooks, professor of meteorology at Harvard University and director of the Blue Hill Meteorological Observatory, *secretary,* and L. T. Samuels, of the U. S. Weather Bureau, *treasurer.*

AT the Washington meeting of the Geological Society of America Dr. Arthur L. Day, director of the Geophysical Laboratory of the Carnegie Institution, was elected president. He succeeds Dr. Charles Palache, of Harvard University. Vice-presidents elected were: Dr. T. Wayland Vaughan, formerly director of the Scripps Institution of Oceanography; Dr. Warren J. Mead, of the Massachusetts Institute of Technology; Dr. Joseph A. Cushman, Cushman Laboratory of Foraminiferal Research, Sharon, Mass., and Dr. Norman L. Bowen, of the University of Chicago. Dr. Charles P. Berkey, of Columbia University, since 1922 secretary of the society, was reelected.

DR. VERNOR C. FINCH, of the University of Wisconsin, was elected president of the Association of American Geographers at the recent meeting held at the University of Michigan to succeed W. L. G. Joerg, of the National Archives, Washington. Other officers elected were: Griffith Taylor, of the University of Toronto, *vice-president;* Guy-Harold Smith, of the Ohio State University, *treasurer,* and Clarence F. Jones, of Clark University, *councilor.* Preston E. James, of the University of Michigan, was reelected *secretary.*

DR. ELLIS THOMSON, of the University of Toronto, was elected at the Washington meeting president of the Mineralogical Society of America, and Professor Kenneth K. Landes, of the University of Kansas, was named vice-president. Dr. Paul F. Kerr, of Columbia University, was reelected secretary.

THE American Mathematical Society has voted that the volume for 1938 of the *Bulletin* of the society be dedicated to Dr. E. R. Hedrick, vice-president of the University of California and provost of the university at Los Angeles, with the following inscription: "By order of the Council of the Society, this volume is dedicated to Earle Raymond Hedrick in appreciation of his services to the society as editor-in-chief of the *Bulletin* for the past seventeen years."

AT the Indianapolis meeting of the American Association for the Advancement of Science the $1,000 prize, given annually for an "outstanding" paper pre-

sented at the meeting, was awarded to Dr. Philip R. White, of the department of animal and plant pathology of the Rockefeller Institute for Medical Research at Princeton, N. J., for a paper presented before the Section for the Botanical Sciences and the Botanical Society of America entitled "Root Pressure—an Unappreciated Force in Sap Movement." The first Theobald Smith award in medicine, established by Eli Lilly and Company, was given to Dr. Robley D. Evans, of the Massachusetts Institute of Technology, for his address entitled "Biophysical Studies of Chronic Radium Poisoning."

DR. ERNEST W. GOODPASTURE, professor of pathology at Vanderbilt University School of Medicine, was presented with the research medal of the Southern Medical Association at the annual meeting, which was held in New Orleans from November 30 to December 3. The award was made in recognition of his investigations of virus diseases.

SIR AMBROSE FLEMING, inventor of the thermionic valve, has been made an honorary life fellow of the Royal Society of Arts, London, "in view of the many services he has rendered to the society during the past fifty years." Only five such fellowships have been conferred during the past ten years.

DR. CARL KOLLER, New York City, who in 1884 introduced cocaine as a local anesthetic in operations on the eye, celebrated his eightieth birthday on December 3.

UNDER the reorganization plan of the College of Agriculture of the University of California the college will be administered as a whole, without designation of branches in either northern or southern parts of the state. Dean Hutchison will retain his titles of dean of the College of Agriculture and director of the Agricultural Experiment Station, at Berkeley; Dr. S. B. Freeborn will be assistant dean and assistant director of the experiment station; Professor B. H. Crocheron will continue as director of the Agricultural Extension Service. At Davis, Professor Knowles A. Ryerson will be made assistant dean of the College of Agriculture, the title of director of the branch of the college being abolished. At Los Angeles, Dr. William H. Chandler, professor of pomology, now at Berkeley, will be placed at the head of the work in agriculture as assistant dean. Dr. L. D. Batchelor will continue as director of the Citrus Experiment Station at Riverside. The positions of director and assistant director of the branch of the College of Agriculture in southern California will be abolished.

THE retirement is announced of seven members of the faculty of the University of Maryland under the State Retirement Act which was passed at the last session of the Legislature. These are: Dr. H. J. Patterson, formerly president of the university and dean of the college of agriculture; Dr. A. N. Johnson, dean of the college of engineering; Dr. H. B. McDonnell, professor of agricultural chemistry; Professor Harry Gwinner, professor of engineering mathematics; Dr. W. T. L. Taliaferro, professor of farm management; J. T. Spann, associate professor of mathematics, and C. J. Pierson, professor of zoology.

DR. JAMES FRANCK, professor of physics at the Johns Hopkins University, has been awarded a grant of $2,000 a year for three years under the Friedenwald Foundation for the study of photosynthesis.

THE Committee on Scientific Research of the American Medical Association has made a grant to Dr. Warren O. Nelson, professor of anatomy at Wayne University, for a study of thymus function and for a continuation of his study on synthetic androgens.

The Cornell Alumni News writes: "Dr. Liberty Hyde Bailey, Agriculture, Emeritus, seventy-nine years young, has returned to his Hortorium in Ithaca from exciting adventure in the South Seas. During a trip to collect palms in some of the uncharted islands of the Bahamas, he and a companion were caught in a tropical storm at sea in an eighteen-foot open skiff, without food and water for five days and four nights, and were raked with gunfire in a native brawl. 'But I got what I went after,' Dr. Bailey says."

L. J. WILD, principal of the Agricultural High School at Feilding, New Zealand, regent of the University of New Zealand, president of the Royal Agricultural Society of New Zealand, who is visiting the United States, recently spent four or five days inspecting the work in progress at the Davis branch of the College of Agriculture of the University of California.

THE delegation from the British Association for the Advancement of Science to the Jubilee Session of the Indian Science Congress in Calcutta, which is being held from January 3 to 9, arrived at Bombay on December 17. Sir James Jeans, who presides at the congress in the place of the late Lord Rutherford, and Dr. O. J. R. Howarth, secretary of the association, were members of the party.

DR. CHARLES GORDON HEYD, New York, past president of the American Medical Association, gave on December 18 the annual William Cline Borden Memorial Lecture in surgery at the George Washington University School of Medicine. His subject was "Thyroid Disease."

DR. WALTER TIMME, professor of clinical neurology,

College of Physicians and Surgeons, Columbia University, delivered the twelfth annual Stanford E. Chaillé Memorial Oration before the Orleans Parish Medical Society, Louisiana. He spoke on "Status Hypoplasticus."

The annual conference of the British Geographical Association was held at the London School of Economics from January 4 to 6, under the presidency of Professor Patrick Abercrombie. His address was entitled "Geography, the Basis of Planning."

Professor E. Cartan, of the University of Paris, has been appointed Rouse Ball lecturer at the University of Cambridge for the year 1937–38.

The fiftieth meeting of the American Physiological Society and the thirty-second meeting of the American Society of Biological Chemists will be held in Baltimore from March 30 to April 2, in conjunction with the meetings of the other organizations comprising the Federation of American Societies for Experimental Biology. The headquarters will be at the Lord Baltimore Hotel.

The annual summer term of the American School of Prehistoric Research will open in Berlin on July 1. The tentative program includes lectures, seminars, museum studies, practice in excavating and excursions to outstanding prehistoric sites in various parts of Germany, Czechoslovakia, Austria, Hungary and Yugoslavia. Dr. V. J. Fewkes, who has been in charge of three previous summer terms, will again be acting director. Students will have opportunities to excavate in several important Neolithic and Iron Age sites. The term will close in Prague on September 10. Prospective students should apply as soon as possible. Applications for enrolment and for further information should be addressed to Dr. George Grant MacCurdy, director of the American School of Prehistoric Research, Old Lyme, Conn.

The proposal of the council of the Royal Society that the number of candidates selected for election annually shall be twenty instead of seventeen was approved at the anniversary meeting on November 30. The first election of twenty fellows will take place in March.

Announcement is made of the forthcoming publication of an "Annual Review of Physiology" in which it is proposed to review the developments of the preceding year or biennium in the major fields of physiological research. The series will appear under the auspices of the American Physiological Society, Inc., and the Annual Review of Biochemistry, Ltd. The new review will conform in general style and format to the "Annual Review of Biochemistry." The Joint Board of Management is to consist of Chauncey D. Leake, University of California; J. Murray Luck, Stanford University; W. J. Meek, University of Wisconsin, and Carl L. A. Schmidt, University of California. The Editorial Committee comprises: A. J. Carlson, University of Chicago; J. F. Fulton, Yale University; M. H. Jacobs, University of Pennsylvania; F. C. Mann, University of Minnesota and the Mayo Foundation, and W. J. Meek, University of Wisconsin. J. Murray Luck will serve as managing editor. The first volume is expected to appear in February, 1939.

The Mt. Desert Island Biological Laboratory at Salsbury Cove, Maine, is planning to offer next summer a course in invertebrate zoology, with special emphasis on marine forms, for college undergraduates and graduates. A new laboratory is being built and will be named "The Isabelle Zabriskie Hegner Laboratory" in memory of the daughter of Dr. and Mrs. Robert W. Hegner, who have given funds for the purpose. Ample supplies of running sea water and other facilities for the study of living animals will be a feature of the laboratory. A maximum of twenty-four students will be accepted. The course of six weeks' duration will be under the general supervision of Professor Ulric Dahlgren, of Princeton University, with the assistance of Professors Gardiner B. Moment, of Goucher College, and J. Wendell Burger, of Trinity College. Special lectures in their respective fields will be given by other members of the laboratory colony, among whom are Professors R. W. Hegner, H. V. Neal, W. H. Lewis, H. W. Smith, E. K. Marshall, Jr., and D. E. Minnich. Prospective students may secure further information from the director, Professor William H. Cole, Rutgers University, New Brunswick, N. J.

On account of the removal of the McCormick Memorial Institute from its own building to the University of Chicago, it has been necessary to find new quarters for the American Type Culture Collection. It is now established in the Georgetown University Medical School, Washington, D. C., with Dr. Mario Mollari, professor of bacteriology, as curator, and Dr. O. A. Bushnell as assistant curator. Dr. Bushnell, who will give full time to the work of the collection, is a graduate of the University of Hawaii, where he specialized in bacteriology and mycology, and has recently taken his doctor's degree at the University of Wisconsin. For several years he has had charge of the maintenance and distribution of the large collection of legume bacteria of the Wisconsin Experiment Station. Through the cooperation of several Washington laboratories it has been possible to increase the number of cultures and enlarge the scope of the collection. Protozoa, which the collection has

never attempted to carry, are now available for distribution.

CONSTRUCTION has been started for the new chemical research laboratory at Brown University, which has been made possible through a gift of $500,000 from Jesse H. Metcalf, formerly United States senator from Rhode Island, a member of the Board of Trustees. The laboratory will provide facilities for research in photochemistry and electrochemistry. Architecturally, it will harmonize with the early Georgian design of other buildings on the west campus. The outside will be brick with white stone and wood trim, 130 feet long, 48 feet wide and 54 feet high. It will adjoin the Jesse Metcalf Memorial Chemical Laboratory, named for the father of Mr. Metcalf. There will be sixty-one rooms for research, conferences, offices and for special technical purposes, accommodating between 30 and 40 graduate research workers. Facilities at the university for advanced chemistry will be doubled when the building is finished. There will be a new divisional library of 60,000 volumes capacity on chemistry, physics and mathematics. Some of the laboratories will be air-conditioned. The largest laboratory will be used for undergraduate instruction in physical chemistry.

DISCUSSION

TUBERCULOSIS, LEPROSY AND OTHER DISEASES CAUSED BY ACID-FAST BACTERIA[1]

THE purpose in preparing this symposium and in publishing in monograph form the papers composing it is to bring into prominence a disease process caused by a group of micro-organisms which, while closely grouped as a family, are yet separated by cultural, chemical, morphological and biological attributes. This family is called the *Acid-Fast Family* for simplicity's sake because all its members, those that cause sickness and those that cause no sickness, have the attribute of retaining dye when attempt is made to bleach this out with an acid or other decolorizing solution. They are called in scientific literature *Mycobacterium,* a genus of the *Mycobacteriaceae* family.

The members of this acid-fast family which are great producers of disease in man are the various strains of *Mycobacterium tuberculosis,* which cause tuberculosis, and of *Mycobacterium leprae,* which cause leprosy. In the animal kingdom various strains of the tubercle bacillus attack our food supply by producing tuberculosis in cattle, fowl, swine and other species. There are also strains of the tubercle bacillus which cause disease only in cold-blooded animals and live only at lower temperatures than are found in the bodies of warm-blooded animals. The Johne's bacillus, another member of this family, also takes heavy toll among cattle and allied species. Bacteria apparently allied to the leprosy bacillus cause a leprosy-like disease in rats and other rodents.

In addition to these disease-producing strains there are numerous strains of the acid-fast family which do not produce disease, for example, the timothy grass bacillus, which lives in the soil or on grasses, or the smegma bacillus, which dwells about the genitals of humans and some animals. Hagan, Rhines and others have succeeded in cultivating many strains of acid-fast bacteria from the soil.

The most striking common feature of the disease process caused by all those strains of the acid-fast family which cause sickness is that, regardless of whether the disease is fatal or not, the germ for part of its life history thrives inside of one cell of the body, known as the monocyte. This monocyte wanders about the body by its own motive power or is transported by blood and lymph stream. It may even carry the germ into the body from the outside, for example from the air passage. Later, rendered sluggish by the germs multiplying within it, the monocyte may stop in any part of the body, and where it stops disease may arise.

There are localities, different in different animals, where apparently the monocyte has special functions to perform. Such places are the lungs, the lymph glands, the gut, the spleen and the liver. As an illustration of this (and this is only one factor in the whole story) various strains of the human tubercle bacillus cause tuberculosis in man most frequently in the lungs, where monocytes are very abundant. This means that the monocytes found in the lungs perform some special function there, which probably means that they have likewise some very delicate or special internal chemistry. It does not require a great stretch of the imagination to conclude that in the early life history of this symbiosis between bacillus and monocyte there is some chemical factor that is common to both through which they contend for the same food supply. The same conclusion is logical about the monocytes of the lungs of cattle and strains of the bovine tubercle bacillus, the monocytes of the large gut of cattle and the Johne's bacillus, the monocytes

[1] Statement introducing the monograph of the American Association for the Advancement of Science, containing the papers presented in the Denver symposium, now in press for publication by The Science Press.

of the skin and nerve sheaths and the lepra bacillus in human leprosy, and so on, through other examples in different species of animals and different strains of acid-fast bacilli.

What the chemical factor is, has, up to now, eluded the investigator, possibly because of the difficulties surrounding the study of the internal chemistry of the monocyte, which does not thrive away from its natural environment in association with the other cells of the body.

Much progress, however, has been made in the study of the chemical processes involved in the life history of the various strains of acid-fast bacilli. The study of the chemical composition of the different strains of bacilli has yielded substances common to the whole family in the three gross divisions of their living tissues, that is, the proteins, the carbohydrates and the fats. This progress has been facilitated by our ability to grow many of the strains of acid-fast bacilli on a simple inorganic food stuff out of which each strain can make, by virtue of its own peculiar living characteristics, its own peculiar tissues. This study of the chemical processes has served to prove that the family is bound together by other bonds than acid-fastness and monocyte-bacterial relationship. And it has also served to isolate some of the distinctive qualities that make the strains what they are, *viz.*, human, bovine, or avian tubercle bacilli, timothy grass bacilli, Johne's bacilli, or leprosy bacilli.

From the same study have been found fractions responsible for the changes the bacilli themselves produce in disease, for instance, the fever, the skin reaction, the stimulation to multiplication and change in the character of the monocyte. The same studies have developed further knowledge on the difficult problem of virulence or the quality that certain strains of bacteria have for certain species of animals to produce severe or not very severe disease. It has been found, for example, that a single strain can be made more virulent at will by modifying the medium on which it grows, a phenomenon probably best exhibited with some of the avian tubercle bacillus strains, which can be made more or less fatal for the rabbit.

It is, however, in the later phases of the various diseases caused by these acid-fast bacteria that the contrasts between them become most marked in spite of their common early picture. The massive skin and nerve deformities of leprosy, the destructive cavity formations of tuberculosis, the stripped gut mucous membrane of Johne's disease, are as widely different pictures as possible, and yet with the microscope one finds the constant association of the acid-fast bacteria and the monocyte cell in all the diseases, even in these later phases.

In the blood serum of bodies infected by the different strains there is found also in immunological studies cross precipitation which binds the group together, but exhibits differences showing specificity as well. In the same way the skin reactions resulting from introducing proteins from the different strains into animals infected with one strain are similar and different mainly in the severity of reactions they cause.

This is of necessity but a short introduction to the substance of the papers which follow in this symposium. With the many similarities that have been pointed out, thought has been given to some word which will attempt to comprehend the diseases here described under a single term. Because the bacteria in the group are in scientific literature called *Mycobacteria,* Dr. Esmond R. Long has suggested the term "Mycobacteriosis," which serves the purpose admirably.

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METHEMOGLOBIN REDUCTION BY GLUTATHIONE OR CYSTEINE

GLUTATHIONE or cysteine is efficient, within the physiological pH range, in reducing methemoglobin to hemoglobin, which is able to combine reversibly with oxygen and carbon monoxide. The reduction has been accomplished *in vacuo,* in air, in hydrogen and in carbon monoxide. For example, in the presence of carbon monoxide and using cysteine as the reductant 1.0 millimole of added cysteine had effected the reduction of 0.6 millimole of methemoglobin (on a heme basis) in 24 hours at room temperature. The initial concentrations in this example were 0.14 millimole of methemoglobin and 0.16 millimole of cysteine per liter. Under identical conditions except for the reductant used, 1.0 millimole of added glutathione effects the reduction of 0.7 millimole of methemoglobin. When considerably larger relative concentrations of cysteine or glutathione are used reduction is complete and almost instantaneous whether in the presence of carbon monoxide, hydrogen or *in vacuo.* In air, reduction is not as complete, presumably because of partial oxidation of the reductant by the atmospheric oxygen.

The glutathione content of the human red cell is relatively high (about 40 mg per 100 cc. of whole blood) and is present almost entirely in the reduced form.[1] The ratio of oxidation-reduction equivalents of glutathione to total pigment in the normal red cell is therefore 1 to 5. It is also well known that when hemoglobin is liberated from the cell it is transformed

[1] S. R. Benedict and G. Gottschall, *Jour. Biol. Chem.,* 99: 729, 1933.

into methemoglobin and thus is no longer active as a physiological oxygen carrier. In view of these considerations we suggest that glutathione is one part of the mechanism which prevents the accumulation of methemoglobin in the intact erythrocyte.

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THE CRYSTALLINE CHARACTER OF LIVING MATERIAL

THE notice in SCIENCE for August 13, 1937, Supplement, page 6, outlining Dr. George A. Baitsell's conclusions concerning the crystalline character of living material is interesting. Dr. Baitsell's work is specially significant from two angles. Firstly, because his conclusions are based upon x-ray investigations; and secondly, because his conclusions can be correlated with similar findings by several workers in the past who used data mostly obtained by microscopic methods. The very close relationship between crystallinity and living structures was realized and extensively advocated by the German scientists, Otto Lehmann, Ernst Haeckel and Friedrich Rinne. The main contention of Rinne's work, "Grenzfragen des Lebens" (1931), is upon the fundamental similarity of crystalline material and organic structure. Rinne in his book also insisted upon the continuity of the organic with the inorganic world.

The writer, in a paper entitled "Iron as the Original Basis of Protoplasm" (1935), shows that the iron bacterium *Leptothrix ochracea* is crystalline. He also summarizes observations on the double refraction of plant cell-wall material, the geometric outline of plant cells and the double refraction of certain chromosomes as general indications of the crystalline character of cellular material. The writer concludes that there are four fundamental factors in the generation of life, and one of these is the aggregation and crystallization of an iron compound, ferrous hydroxide.

On a general basis, all these relationships between crystalline and morphological phenomena can be reduced to the conceptions of modern atomic physics. R. Fuerth, of Prague, especially, has applied physical conceptions to structures and functions of organisms (*Die Naturwissenschaften*, 16: 777, 1928). On this basis, not only organic structures but organic functions are reduced to electromagnetic fields.

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POLLEN AND HAY-FEVER

WHILE the recognition of pollen as the cause of hay-fever is general, apparently the behavior of the inhaled pollen does not seem to be clearly understood. At any rate, when I asked for information on this subject from medical men, who I took for granted could give me the desired data, I was rather taken aback when I was told they could give me no references bearing on this subject. Further questioning brought out the admission that they had never thought of the pollen grain as a living thing, comparable to bacteria or other pathogenic organisms.

When it was first shown that pollen was responsible for the symptoms of hay-fever, it at once seemed to me that the inhaled pollen spores might very probably find the moist mucous membranes a favorable medium for germination. The rapid germination, accompanied by the excretion of enzymes associated with the penetration of the tissue of the host by the pollen tube, would presumably immediately set up the characteristic irritation of the mucous membrane, and through the pollen tube the proteins of the pollen spore would be discharged into the tissue of the host.

The germination of pollen is a routine experiment in the botanical laboratory, where in an ordinary sugar solution of about ten per cent. many species will germinate promptly, the protrusion of the pollen tube sometimes occurring within a few minutes.

Assuming that the above theory is correct, it may be inferred that the pollen grains falling on the moist mucous membrane of the nasal passages might in a few minutes send out the pollen tube, exactly as a fungus spore germinates, and quickly initiate the characteristic symptoms of the disease.

The demonstration of the presence or absence of germinating pollen should not be a difficult matter and, if germination does occur, it certainly should offer a wide field for experiment.

It seems hardly possible that experiments along these lines have not been made, and I should very much appreciate any information on the subject.

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QUOTATIONS

SCIENCE'S MAGNA CHARTA

IT took the British Association for the Advancement of Science a decade to realize that a biologist, a physicist or chemist is not an anchorite of the laboratory but a responsible member of society. The realization bore fruit at the historic Blackpool meeting of 1936. There English men of science awakened socially. Possibly the present Indianapolis meeting of the American Association may be equally significant. A symposium on "Science and Society" will give our

leaders in research an opportunity to interpret their relation to a stricken world which is trying desperately to adapt government to this age of science and invention. It is therefore gratifying to note that the open letter addressed a few months ago by Mr. Ritchie Calder of *The London Daily Herald* to Lord Rayleigh, president of the British Association, on the part that science should play in saving democracy and itself, has inspired Dr. F. R. Moulton to lay before the Council of the American Association the proposition that science has a social task to perform and that it can no longer remain indifferent to the rising tide of totalitarianism. If democracy falls, science falls too—science of the type with which the names of Galileo, Newton, Darwin and Einstein are linked.

Dr. Moulton sees the American Association entering a new phase of its evolution because of the many special societies that have split from it by a process of fission. Yet, powerful as it ever was, it represents organized science as a whole. It is the one body in this country that can speak for the ideals, the internationality, the objectivity that have made science an irresistible culture force, the one body that can tell us "what matters may be of the greatest immediate importance for the future of civilization," to use Dr. Moulton's words.

With the British Association already convinced that the mere accumulation of scientific knowledge does not in itself guarantee the continued welfare of mankind and the American Association listening to Dr. Moulton, the time seems ripe to carry out Mr. Calder's proposal for a Magna Charta, a declaration of independence which shall state the function of science in modern society and the need of freedom of research, freedom of theorizing, freedom of discussion. If the councils of the two associations will together formulate and announce the simple principles that guide scientific men and proclaim the might and sanctity of scientific thought, the world is bound to listen and to profit. Scientific men in all countries are spiritually welded together by a community of interest and an idealism which contrasts markedly with fascistic nationalism and communistic class hatred. They set an inspiring example of devotion to a cause that knows no country, no creed, no race. They prove that collective thinking for the common good is possible. The time has come to let their voices cry out in unison on both sides of the ocean. A spiritual message needs to be conveyed which is not yet understood of all men.—*The New York Times.*

THE PROBLEM OF THE SCIENTIST

THE American Association for the Advancement of Science opened its annual meeting in Indianapolis yesterday. If the sessions fulfill the promises which have been made for them they should have an unusual importance. It has been planned to use this meeting to consider first steps toward creating, in cooperation with the British Association for the Advancement of Science, an "International Democratic Commonwealth of Intellectual Resources." Its purposes would be to integrate and focus the knowledge of a great court of scholars in order that this knowledge might be more consistently applied to world problems and also to defend the freedom of the scientist.

The movement seems to have originated at the Harvard tercentenary conference of scholars and the meeting, in the same year, of the British association. More recently, impetus was given by a letter addressed by an English journalist to the president of the British group, asking that the proposals of last year now be implemented, and an editorial in the New York *Times* of October 17, calling for "an organization which shall indicate how the objective attitude of the laboratory may be applied in governing a people, in breaking down prejudices, in preventing war, in solving problems that mean progress not in one country alone but the world over."

In the past we have frequently remarked the increasing concern of men of science with the contemporary socio-economic problems on the one side and, on the other, the growing popular feeling, under the impact of a variety of political failures, that it would be desirable to try to adapt the techniques and methods which have worked well in the sciences to promlems rarely touched in the past by the learned man. These two trends of opinion apparently motivate the present undertaking.

However, there is great difference between organizing to protect the freedom of science and organizing with the intention of placing science's resources more fully at the service of government. About the former there would be no disagreement among reasonable men in democratic countries, and a strongly knit body of scientists of eminent reputations and militant dispositions might do much to strengthen the bulwarks of the liberty they have won through the centuries.

It will be quite another thing to carry out the second part of the program if it is accepted in principle. That would call not only for a higher degree of the unification of knowledge than has yet been achieved but for the formulation as well of basic political attitudes—a task that would open the way for violent clashes of opinion. It remains to be seen whether, with the best will in the world, even the scientists, who, after all, are citizens, too, will be able not only to pool their intellectual resources but agree upon how these resources are to be used, and who is to use them and for what ends.—*The Baltimore Sun.*

SPECIAL ARTICLES

AN ULTRACENTRIFUGAL STUDY OF CATALASE

THE enzyme catalase is interesting not only for its own sake but also because of its close relationship to hemoglobin. Like methemoglobin, and probably also peroxidase, it consists of *proto-ferriheme* in combination with a carrier protein.[1] The protein serves the double purpose of activating the catalytic properties of the prosthetic heme grouping and of rendering its action highly specific. Very probably different animals have slightly different catalases just as they have their characteristic hemoglobins. This is borne out by the fact that Sumner and Dounce's recent chemical method[2] for the crystallization of beef liver catalase does not yield crystalline horse liver catalase. The difference appears to be in the protein part rather than in the prosthetic group. We have prepared horse liver catalase in highly purified form with the help of an air-driven quantity ultracentrifuge.[3] The steps taken to achieve this purification have been determined by estimations of specific activity and hemin content combined with observations in the analytical ultracentrifuge. The latter have at the same time given definite information about the molecular composition of the various fractions; the sedimentation constants calculated from them provide a measure of the molecular weight of the enzyme.

The purification of horse liver catalase by adsorption and elution[4] ordinarily yields brown solutions which are free from hemoglobin, show an activity (k) of 1,000–6,000 and a purity (Kat.f.) of 4,000–9,000 [occasionally higher figures have been reported[4, 5]]. When such solutions are examined with the analytical ultracentrifuge they usually show evidence of containing three molecular species. The predominant species has a sedimentation constant of 11×10^{-13} cm sec^{-1} dynes^{-1}; this undoubtedly is the enzyme. There is also present some light "unsedimentable" matter and varying amounts of a heavier material with rather diffuse sedimenting boundaries corresponding to $s_{20^\circ} =$ ca 65×10^{-13} cm sec^{-1} dynes^{-1}. This heavy substance has been purified by throwing it down as pellets in the quantity ultracentrifuge. It redissolves readily in water or saline to give colored solutions with a maximum of light absorptio ı in the violet. Its specific catalytic activity is relatively low. We are continuing the study of the properties of this substance which, if it is a protein, probably has a molecular weight of the order of three to four millions.

We have purified the enzyme by successively concentrating it as a black-brown bottom layer in the centrifuge tube. The activity (k) then has ranged between 11,700 and 161,000 and the purity (Kat.f.) between 8,500 and 33,400. While the enzymatic hemin content of the original preparations varied between 10 and 35 milligrams per liter, the bottom solutions contained from 187 to 906 milligrams per liter. The total dry weight-to-hemin ratio has been decreased from 400–600 to 100–279. These products compare favorably in activity and iron content with the crystalline beef liver preparations of Sumner and Dounce.[5] The sedimentation constant, $s_{20^\circ} = 11 \times 10^{-13}$, indicates that horse liver catalase molecules are considerably heavier than those of hemoglobin. Provided the enzyme has the same density as most other proteins and a more or less normal diffusion rate[6] its molecular weight should be in the neighborhood of 250,000–300,000.

Several analytical photographs have been made from a nearly pure catalase preparation from beef liver. The resulting sedimentation constant, $s_{20^\circ} = 12 \times 10^{-13}$, is substantially the same as that for purified horse liver catalase.

A more detailed description of these experiments will shortly be published.

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[1] K. G. Stern, *Yale J. Biol. and Med.*, 10, 161, 1937. A review.
[2] J. B. Sumner and A. L. Dounce, *J. Biol. Chem.*, 121, 417, 1937.
[3] R. W. G. Wyckoff and J. B. Lagsdin, *Rev. Sci. Instruments*, 8, 74, 427, 1937.
[4] K. Zeile and H. Hellström, *Z. physiol. Chem.*, 192, 171, 1930.
[5] H. v. Euler and K. Josephson, *Liebig's Ann.*, 454, 158, 1927.
[6] T. Svedberg, *Nature*, 139, 1051, 1937.

THE ESSENTIALNESS OF MANGANESE FOR THE NORMAL DEVELOPMENT OF BONE

THE first report that perosis, a deformity of the tibio-metatarsal joint of young chickens, was due to a deficiency of manganese in the diet was made by Wilgus, Norris and Heuser[1] in 1936. Confirmation of these results has been reported by several laboratories.[2,3,4]

In recent experiments carried out with New Hampshire chicks fed a low-manganese diet (Mn, 10 p.p.m.) the development of perosis was studied by means of the x-ray.[5] X-ray pictures were taken of the leg bones and in some instances of the wing bones, at regular

[1] H. S. Wilgus, Jr., L. C. Norris and G. F. Heuser, SCIENCE, 84: 252, 1936.
[2] W. D. Gallup and L. C. Norris, *Jour. Biol. Chem.*, 117: xxxvi–xxxvii, 1937.
[3] V. G. Heller and R. Penquite, *Poultry Sci.*, 16: 243–246, 1937.
[4] Personal communications to the authors.
[5] The x-ray pictures were taken by Dr. L. L. Barnes, Cornell University.

intervals from the time of hatching until the chicks were seven weeks old. Likewise, pictures were taken of control chicks that received the same basal diet with the manganese content adjusted to 100 p.p.m. Although calcification appeared normal in both groups, the bones of the chicks on the low-manganese diet were observed to be perceptibly shorter and thicker at the twenty-fourth day of age than those of the controls. Bone measurements were made from the x-ray films of the chicks on the low-manganese diet showing by gross observations no characteristic deformities of perosis and compared to those of the controls of the same sex and age and of approximately the same weight. The smaller gains in weight and high incidence of deformities among the chicks that received the low-manganese diet limited the number of comparisons possible. However, in practically all cases, the measurements confirmed these observations.

Measurements were then made of the leg bones of a strain of chicks which had proven very susceptible to perosis when placed on a manganese-deficient diet. These chicks together with suitable controls receiving adequate amounts of manganese were sacrificed at four and five weeks of age. At four weeks of age, the tibiae and metatarsi of the chicks on the low-manganese diet were approximately 7 per cent. shorter than the corresponding bones of their controls of the same age and of about the same weight (± 10 grams). The results were obtained from fourteen comparisons in which the bone length of the control chick exceeded in all but one instance that of the chick on the low-manganese diet. Twelve such comparisons made with chicks five weeks old showed similar differences in eight instances, and no appreciable difference in four instances. Seven comparisons of length of tibiae made at six weeks of age on a rapidly growing strain of New Hampshire chicks gave differences which again favored the control chicks in every instance with an average difference of 8 per cent. Studies now in progress with White Leghorn chicks which are not very susceptible to perosis indicate that the bone development of this breed of chicks is also affected by manganese deficiency in the same manner as that of the New Hampshire chicks.

These facts agree with a concurrent observation that a large percentage of chicks hatched from eggs of low manganese content[6] have short leg bones and with a report by Lyons and Insko[7] that chondrodystrophic embryos characterized by shortened and thickened legs, short wings and other deformities were produced from the eggs of hens fed manganese-deficient diets. According to these workers the deformities could be prevented by manganese supplements in the diet of the hen, thereby increasing the manganese content of the egg, and by direct injection of manganese into the egg previous to incubation. Other investigators[8] have noted that "the shafts of the bones often appeared to become shortened and thickened" in chicks on diets that produced perosis.

The wide distribution of manganese in biological material and its possible function in metabolism has been commented upon by VonOettinger.[9] In a study of manganese distribution in animal tissues Lund, Shaw and Drinker[10] reported that the bones of rabbits contained 0.101 mg of manganese per 100 gm of fresh bone. Reiman and Minot[11] found 0.047 mg of manganese per 100 gm of bone marrow in dogs that had been fed manganese ores. Skinner, Peterson and Steenbock[12] found 0.038 and 0.034 mg of manganese per 100 gm in the shaft and head, respectively, of fresh bone. Only traces were found in the marrow. By feeding a diet of high manganese content, the latter investigators were able to increase the manganese content of the bones of rats from 0.079 mg per 100 gm of dry material to 0.221 mg. In recent studies[13] of manganese metabolism during early growth the minimum amount of manganese found in the leg bones of chicks that received a manganese-deficient diet was 0.060 mg per 100 gm of dry material. A reasonably constant value of 0.200 mg was found in the bones of chicks that received adequate manganese. Partial depletion of the bones in manganese resulted in deformities at the joints and at the ends of the bones.

It appears from these results that manganese in small amounts is a necessary constituent of bone in the chick and that it is essential for normal bone development in addition to preventing other deformities resulting from or coincident with perosis. The presence of manganese in the bones of other species, particularly in the shaft and head, indicates that it may be essential for bone development in general. The fact that gross symptoms of perosis have not been recognized in animals other than the fowl may be related to differences in anatomical structure of the skeleton and in manganese requirements.

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[6] W. D. Gallup and L. C. Norris, *Poultry Sci.*, 16: 351–352, 1937.

[7] M. Lyons and W. M. Insko, Jr., *Ky. Agr. Exp. Sta. Bul.*, 371, 1937.

[8] H. S. Wilgus, Jr., L. C. Norris and G. F. Heuser, *Poultry Sci.*, 16: 232–237, 1937.

[9] W. F. Von Oettingen, *Physiol. Rev.*, 15: 175–201, 1935.

[10] C. C. Lund, L. A. Shaw and C. K. Drinker, *Jour. Exp. Med.*, 33: 231–238, 1921.

[11] C. K. Reiman and A. S. Minot, *Jour. Biol. Chem.*, 45: 133–148, 1920.

[12] J. T. Skinner, W. H. Peterson and H. Steenbock, *Jour. Biol. Chem.*, 90: 65–80, 1931.

[13] Unpublished results.

STUDIES IN THE PHYSIOLOGY OF THE THYMUS

EXPERIMENTAL attempts to determine the function of the thymus gland have been in progress nearly a century. The approach has been by one of four methods: (1) Thymectomy; (2) the use of thymus extracts; (3) thymo-toxic sera; (4) x-ray destruction of the thymus.

Of these, thymectomy appears to have been most popular. We selected the x-ray approach because we felt it offered the best means of destroying the thymus. The rat was chosen as the first animal for study for a number of reasons that are not pertinent here. All animals used were of the Wistar strain and were maintained on the standard Wistar diet.

Following numerous experiments, we found that approximately 2,200 R delivered to the skin over the thymus destroyed the gland completely. The animals were treated through an eight millimeter anterior portal over the thymus which, before treatment, was localized fluoroscopically. The rest of the animal was adequately protected from any x-ray exposure. Another important feature of our approach was the age of the animal when treatment was started. All rats were treated within forty-eight hours after birth, 550 R being delivered to the skin over the thymus on four successive days. We believe that this has been one of the most important factors that permitted reproducible results in successive litters. It is our opinion that the conflicting results reported in the thymus literature of the past century were, in a large measure, due to the different age periods of the animals on which experiments were started.

Following thymus destruction early in the life of the rat, we saw a number of striking changes, some of which we feel have been observed long enough to justify a report. All observations were made on litter mates. Both sexes showed a slowing up of general bodily development as measured by weekly weight curves. For approximately three weeks after birth, no appreciable difference in the weights of the treated and control animals was noted; whereas, a spreading of the weight curves was generally observed after this period. This was more consistent and more marked in the male group.

The most striking organ changes were noted in the gonads, particularly in the male. With complete destruction of the thymus, the development of the testicle was practically arrested. Especially striking was the microscopic picture. In that of the treated animal, there was almost a complete disappearance of the germ cells, with no attempt at spermatogenesis.

The effect on the female gonad was relatively very slight. Although grossly somewhat smaller in the treated animal in most instances, no real differences from the control ovary could be seen microscopically. The estrus cycle remained normal in all our animals. When mating was effected, we again saw the striking differences between the sexes in those animals in which the thymus had been destroyed. No successful mating was obtained with treated male and treated female. The same was true when treated male was crossed with control female. In all instances in which we mated a treated female with a control male, litters were successfully cast, which up to the present are not inferior to those cast by the control animals.

Studies of the effect of thymus destruction on all the other endocrine glands are still being carried out as well as numerous control observations. While sufficient time has not elapsed to permit a detailed examination of all the other glands, certain striking changes in some of them have already been noted. In computing the organ-weight and body-weight ratios, findings consistently showed that in the male animals there was a striking decrease in the weight of the testicles with a relative increase in weight of the pituitary and adrenals, but these ratio changes were not consistent in the female group. In the male, we saw the development of the typical picture of the castrate pituitary with its hypertrophied vacuolated basophiles. This, however, was not found in the female pituitary. At the moment, we believe these pituitary effects are secondary to the testicular changes, since these changes represent essentially a physiological castration.

In spite of the fact that the thymus was effectively destroyed in both sexes, the marked effects on the testicle and the lack of striking changes in the ovary, the failure to influence the estrus cycle, the sterile male and the failure to alter the reproductive function in the female, the typical castrate pituitary in the former and the relatively unchanged pituitary in the latter, the less striking general body-weight changes and the absence of any consistency of organ-weight and body-weight ratio changes in the female prompted us to consider the possibility that the thymus functionally plays a different rôle in the two sexes.

Certainly our data indicate a close relationship between the function of the thymus and the proper development of the testes.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

A BLEACHING AND CLEARING METHOD FOR PLANT TISSUES

For the study of floral anatomy, the importance of which in tracing out the intricate evolutionary interrelationships of the angiosperms has long been recognized, the classical method is the very accurate but slow and laborious one of reconstructing the anatomical pattern from a long series of prepared sections. The drawback of this method is that time permits the study of only a few representative types, and only those species can be investigated of which fixed material is available to the worker. The following method, which was devised for the study of the anatomy of the florets of the Compositae, is not only so rapid that fifty or a hundred organs could be prepared for study within a week, but in addition it can be used equally well (or even better) on herbarium material, so that any species of which a herbarium specimen is available can be classified as to its type of floral anatomy.

The procedure is as follows: remove the flower or organ from the plant or dried specimen, and boil 2 to 3 minutes in water. Then place in a mixture of concentrated ammonium hydroxide (NH_4OH) and hydrogen peroxide (H_2O_2) of varying proportions, depending on the nature of the specimen. For relatively colorless objects 2 parts NH_4OH to 1 part H_2O_2 is best, but if the organ contains much chlorophyll, or if it is a badly oxidized, brown or blackish herbarium specimen, high concentrations of H_2O_2, up to 1 to 1 mixture, are necessary. For most objects 24 hours in this solution is sufficient, but for unusually opaque organs and badly discolored herbarium specimens the solution should after this time be renewed, and the specimen treated for a second or even a third day. Great care should be taken in pouring off the liquid, since the specimens are at this stage very soft and fragile. Then place in 95 per cent. alcohol and leave from 1 to 12 hours, depending on the time needed for the material to harden and the bubbles formed by the H_2O_2 to be driven out. Excess bubbles may then be removed by gently tapping the object or by pricking with a fine, sharp needle. Then place in n-butyl alcohol, using 3 changes at 1- to 2-hour intervals, then 1 to 1 mixture of butyl and xylol, 100 per cent. xylol, and mount in balsam. Staining with aqueous gentian violet (1 per cent.) is possible after hardening in alcohol, but most preparations can be studied equally well or even better without staining.

This method removes the cell contents and makes the cellulose walls transparent, so that the lignified protoxylem strands of the vascular bundles stand out sharply. It is ideal for small objects, like the florets of most Compositae, and can be used for organs up to about 2 mm in thickness, such as whole flowers of *Cornus,* although best results on relatively large specimens are obtained by preparing some whole and splitting other specimens of the same material down the middle, or by pressing them gently between a slide and cover glass after treatment with ammonia-peroxide, and hardening them on the slide by flooding it with alcohol. For unusually simple objects, like the ovaries at anthesis of *Lactuca* or *Taraxacum,* satisfactory temporary preparations can be obtained from dried ones that are not badly discolored by merely boiling them, first in water, then in concentrated ammonia. Difficulties are encountered with this method when the organ contains sclerenchymatous tissues, large secretions of oily or fatty substances, or a heavy coat of pubescence, although the latter can often be scraped away with a sharp scalpel from fresh, living specimens or from dried ones just after the preliminary boiling. While the method is obviously not suitable for working out the principles of floral anatomy, it is ideal for studying the distribution of the various anatomical types which have been worked out from sectioned material, so that they may be used as additional criteria in systematic and phylogenetic studies of genera and families of angiosperms. The following two examples illustrate the use of this method.

(1) *The stigma of some apocarpous dicotyledons.* The work of Eames[1] has definitely established the follicle as the most primitive type of carpel, while Hunt[2] has shown that certain types of stigmas clearly show the homology of the carpel with a foliar organ or sporophyll. The discovery, therefore, in a plant otherwise primitive of a follicle whose stigma contains an elaborate branch system is valuable evidence in favor of this theory of the carpel. Such a follicle and stigma exists in the genus *Paeonia,* while the branching type of stigma anatomy occurs in *Actea spicata* L., (Ranunculaceae), *Akebia quinata Decne* and probably all other *Lardizabalaceae,* and in *Uvaria purpurea* Blume of the *Anonaceae.* In the first three genera, the stigma is supplied by the ventral as well as the dorsal bundles, so that it is derived from the trilobate type of sporophyll (*cf.* Hunt, *loc. cit.,* Fig. 7). The branching system is the most elaborate in *Paeonia,* in which the dorsal bundle may have 8 successive bifurcations within the stigma, and the ultimate number of branchlets is in the hundreds. In *Actaea* and *Akebia* the branches are relatively much reduced and crowded. In *Uvaria* the broad stigma is supplied by the elaborate branching of the dorsal bundle, while the two ventrals end at the summit of the carpel proper with a few short branchlets, one of which fuses with the dorsal bundle. In the achene of *Hydrastis cana-*

[1] A. J. Eames, *Am. Jour. Bot.,* 18: 147–188, 1931.
[2] K. W. Hunt, *Ibid.,* 24: 288–295, 1937.

densis L. (*Ranunculaceae*), the stigma is fundamentally trilobate, but here the branching of the dorsal bundle is much reduced, while two or three major branches of each ventral divide again once or twice to produce the greater part of its vascular supply. In *Helleborus foetidus* L. the ventrals go part way up the linear style, where they fuse with the branched dorsal bundle, while in *Trollius laxus* Salisb. this fusion occurs at the summit of the carpel proper. In *Dillenia Reifferscheidia* Vill. (Dilleniaceae), the two ventrals each branch once and end in the middle of the broadened, but elongate style, while the dorsal continues to its end.

(2) *The ovary of the Cichorieae.* Although the anatomical pattern described by Koch[3] for *Lapsana* is identical with that of all other Cichorieae as regards the corolla, stamens and stigma, considerable variation has been found in the structure of the achenes, and this has proved a valuable aid in delimiting some of the genera of this complex group, and in determining the phylogenetic position of the species. It has already been used in distinguishing between *Lactuca* and *Ixeris,* which latter genus, though unquestionably distinct and actually more nearly related to *Crepis* as has been pointed out by the writer,[4] has regularly been confused with the former. In the genus *Prenanthes,* almost all its species differ from their relatives in *Lactuca* and *Hieracium* in possessing not only five main bundles within the ovary, but in addition one to twelve supernumerary ones. The homology of all these is not yet clear, but in some species the dorsal carpellary bundles are free from those of the corolla, in others the ventral bundle or bundles appear to be extended up into the ovary wall beyond the insertion of the trace to the basal ovule, while still others apparently possess more or less vestigial calyx bundles. Closely paralleling *Prenanthes* in ovary anatomy is the group of Sino-Himalayan high alpine plants generally referred to *Crepis* as the section *Glomeratae,* but which, on the basis of anatomy as well as the external morphology of the corollas, stigmas and achenes, should be placed in a separate genus more nearly related to *Prenanthes* than to *Crepis.*[5] A treatment of this genus is to be undertaken in the near future. In the case of both the *Glomeratae* and *Ixeris* floral anatomy has proven a valuable aid to systematic classification in groups of which preserved material of critical species would be difficult or impossible to obtain.

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UNIVERSITY OF CALIFORNIA,
BERKELEY, CALIF.

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A SUBSTITUTE FOR WHITE INK FOR USE ON SHELLACKED KYMOGRAPH TRACINGS

THE use of white ink for writing on shellacked kymograph paper has proved very unsatisfactory. The fact that it chips and rubs off the paper makes it hazardous to add notes to a tracing. The writer has found that titanium dioxide added to white shellac makes an excellent preparation for this purpose. The advantages are that it can be applied with an ordinary pen—a stub point held sideways serving to the best advantage; it dries rapidly and is permanent; it does not rub off on handling or brushing; it photographs well and contrast slides are excellent.

Titanium dioxide is rubbed up to a soft paste with white shellac, and then more shellac or alcohol is added to give proper consistency. This will vary with the type of pen point used and the manner of individual writing. A slow motion in writing is necessary, and only a small amount of material is applied to the point. If the point is kept clean by frequent wiping and dipping in alcohol, there will not be an accumulation of pigment on the point.

Other substances used for pigment have proved un satisfactory. Zinc oxide does not cover well and gives a distinct bluish cast to the writing. Lead salts apparently are too heavy to flow easily.

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BOOKS RECEIVED

ALBERT, A. ADRIAN. *Modern Higher Algebra.* Pp. xiv + 319. University of Chicago Press. $4.00.

BURNET, F. M., E. V. KEOGH and DORA LUSH. *The Immunological Reactions of the Filterable Viruses.* Pp. 227–368. University of Adelaide, Australia. 10s.

FROLOV, Y. P. *Pavlov and His School; The Theory of Conditioned Reflexes.* Pp. xix + 291. 26 figures. Oxford. $4.00.

GOLDBLATT, L. A. *Collateral Readings in Inorganic Chemistry.* Pp. 225. Appleton-Century. $1.35.

GRAY, ALBERT A. *The Basis of Tissue Evolution and Pathogenesis.* Pp. xix + 92. Jackson, Son & Co., Glasgow, Scotland. 7/6.

Handbook of Scientific and Technical Societies and Institutions of the United States and Canada. Third edition. Pp. 283. National Research Council, Washington. $3.50.

HUBBLE, EDWIN. *The Observational Approach to Cosmology.* Pp. vi + 68. Illustrated. Oxford. $4.00.

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